NACA RM L57B26

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RESEARCH MEMORANDUM

INVESTIGATION OF STATIC LONGITUDINAL STABILITY
CHARACTERISTICS AT TRANSONIC SPEEDS OF 30° SWEPTBACK
WING IN WING-BODY CONFIGURATION WITH AND
WITHOUT HORIZONTAL TAIL

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
April 22, 1957

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INVESTIGATION OF STATIC LONGITUDINAL STABILITY CHARACTERISTICS AT TRANSONIC SPEEDS OF 30° SWEPTBACK WING IN WING-BODY CONFIGURATION WITH AND WITHOUT HORIZONTAL TAIL

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SUMMARY

An investigation of the static longitudinal stability characteristics of two wings of different construction and slightly different flexibilities was made in the Langley 16-foot transonic tunnel. The wings had the same external dimensions: 30° sweepback of the quarter-chord line, a taper ratio of 0.2, an aspect ratio of 3, and NACA 65A004 sections parallel to the model center line. One wing was constructed of steel; the other wing was constructed of plastic reinforced by a steel core. Each wing was tested in wing-body configurations; the reinforced-plastic wing was also tested in a wing-body configuration with horizontal tail. The investigation was made at Mach numbers ranging from 0.80 to 1.03 with angles of attack from -2° to 26°.

The wing-body configuration with the horizontal tail was longitudinally stable for all test conditions. There was an increase in stability with increasing Mach number. The two different types of wing construction had little effect on the longitudinal aerodynamic characteristics of the model.

INTRODUCTION

Investigations have indicated that, for thin low-aspect-ratio wings, moderate leading-edge sweep provides satisfactory stability characteristics at subsonic speeds (refs. 1 and 2). In order to establish the detail load and stability characteristics of such a plan form throughout the transonic speed range, a wing with an aspect ratio of 3, a taper ratio of 0.2, 30° sweepback of the quarter-chord line, and with NACA 65A004 airfoil sections was selected, and the longitudinal stability

[redacted]

characteristics are presented in this paper. This wing is one of several wings being studied in a general wing program at the Langley 16-foot transonic tunnel. Aerodynamic characteristics of other wings in the program have been presented in references 3 and 4.

Two geometrically identical wings were investigated. The first wing was covered with plastic and had a steel core. The construction of this wing was an attempt to devise a cheaper and faster method of wing construction. The other wing was an all-steel wing used for purposes of comparison to check the effect of aeroelasticity and to establish the validity of data obtained with the less rigid reinforced-plastic wing. Under typical loads imposed during these tests, at a Mach number of 1.00 and an angle of attack of 20°, the changes in angle of attack at the wing-tip sections were -0.4° and -0.9° for the all-steel and reinforced-plastic wings, respectively.

SYMBOLS

b wing span

c_{av} average wing chord

$\bar{c}$ wing mean aerodynamic chord

C_D drag coefficient, Drag/qS

C_L lift coefficient, Lift/qS

C_m pitching-moment coefficient, about quarter-chord point of $\bar{c}$, Pitching moment/$qS\bar{c}$

$C_{p,b}$ base-pressure coefficient, $\frac{p_b - p}{q}$

i_t angle of incidence of horizontal tail with respect to body center line, deg

M free-stream Mach number

p_b static pressure at model base

p free-stream static pressure

q free-stream dynamic pressure

S	total wing area, bc_{av}
R	Reynolds number based on $\bar{c}$
α	angle of attack of body center line, deg
$C_{m_{i_t}}$	horizontal-tail-effectiveness parameter near zero lift, $\frac{\partial C_m}{\partial i_t}$

$$C_{m_{C_L}} = \frac{\partial C_m}{\partial C_L}$$

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha}$$

MODEL AND APPARATUS

The investigation was conducted in the Langley 16-foot transonic tunnel, an octagonal slotted-throat single-return wind tunnel operated at atmospheric stagnation pressures (ref. 5). The Mach number at the test-section center line has a maximum variation of ±0.002 in the vicinity of the model.

The model was supported by a sting which had a diameter of 4.75 inches at the model base and a taper of 1.1 inch per foot. This sting was attached to a six-component wire strain-gage balance within the fuselage.

Each of the two wings tested had 30° sweepback of the quarter-chord line, an aspect ratio of 3, a taper ratio of 0.2, and NACA 65A004 airfoil sections parallel to the model center line. One wing was made from steel; the other wing had a steel core covered with Fiberglas-Paraplex laminate and is referred to as the reinforced-plastic wing in this paper. Calculated wing-tip twist due to bending and torsion in the reinforced-plastic wing was about 2.5 times as large as the calculated wing-tip twist for the steel wing at the same loading conditions. These calculations were based on wing influence coefficients from dead-weight loadings and pressure distributions. Each wing was mounted on the fuselage center line and tested without incidence or dihedral.

The fuselage was a steel-shell body of revolution with a fineness ratio of 11, an ogive nose, cylindrical center section, and a slightly boattailed afterbody. A steel horizontal tail was mounted on the model center line. The tail had an area of 1.64 square feet, an aspect rati

of 4.0, 45° sweepback of the quarter-chord line, and was set at an angle of incidence of -4° for the wing-body configuration with horizontal tail. The ratio of horizontal tail span to wing span was 0.517. Other details of the model are shown in figure 1.

A pendulum-type strain-gage inclinometer was mounted on the wing butt to determine angle of attack.

TESTS

The tests were conducted at six Mach numbers from 0.80 to 1.03 and an angle-of-attack range of -2° to 26° except as limited by allowable stress in the model support structure. Data were obtained for both steel and reinforced-plastic wings in the wing-body configuration and for the reinforced-plastic wing in a wing-body configuration with horizontal tail. There was no fixed transition.

The Reynolds number based on the mean aerodynamic chord was between 7.0×10^{6} and 8.5×10^{6}.

ACCURACY OF MEASUREMENTS

The data presented herein were not adjusted for tunnel-wall interference (wall-reflected disturbances) inasmuch as this correction was generally negligible at Mach numbers up to 1.03 in this tunnel (ref. 6). The indicated angle of attack was corrected for tunnel-flow angularity. Lift and drag data were adjusted to the conditions of free-stream static pressure at the model base. Drag coefficient was not corrected for sting effects; however, reference 7 indicated these would be small. Base-pressure coefficient as a function of angle of attack at various Mach numbers is shown in figure 2. The curve shown is a faired average of tail-off and tail-on data.

Based on balance accuracy and repeatability of measurements, the accuracy of the data is believed to be within the following limits:

C_L	±0.01
C_D	±0.004
C_m	±0.003
α, deg	±0.1
$C_{p,b}$	±0.01
M	±0.005

RESULTS AND DISCUSSION

The basic aerodynamic data for the reinforced-plastic wing in the wing-body configuration, with and without the horizontal tail, are presented in figure 3. A comparison of the aerodynamic characteristics of the wing-body configuration with steel wing and reinforced-plastic wing and without horizontal tail is shown in figure 4. Figures 5 and 6 present the lift-curve slope, longitudinal stability parameter, and horizontal-tail effectiveness as a function of Mach number for the wing-body configuration with reinforced-plastic wing, with and without horizontal tail.

Characteristics of Wing-Body Configuration With Horizontal Tail and Reinforced Plastic Wing

The tail-off configuration showed some static longitudinal instability at the higher lift coefficients between Mach numbers of 0.90 and 1.00; however, the addition of a horizontal tail made the model stable at all test conditions. (See fig. 3(b).) The change in longitudinal stability parameter (fig. 5(a)) from approximately 0 at a Mach number of 0.80 to -0.13 at a Mach number of 1.03 for the tail-off configuration represents a 13-percent increase in stability. For the tail-on configuration, this parameter was -0.05 to -0.15, or an increase of 10 percent of the mean aerodynamic chord. Two-thirds of this increase in stability occurred in the narrow Mach number range from 0.90 to 0.94. The complete model had a trim lift coefficient of 0.67 at a Mach number of 0.80 with the horizontal tail mounted at an angle of incidence of -4° and the assumed center-of-gravity location at the $\bar{c}/4$. (See fig. 3(b).) The aforementioned increased stability at higher Mach numbers reduced the trim lift coefficient to about 0.41 at $M = 1.03$. For an assumed wing loading of 70 pounds per square foot, these trim lift coefficients represent an altitude of about 51,000 feet. The horizontal-tail-effectiveness parameter $C_{m_{i_t}}$ (which was obtained by assuming the horizontal-tail pitching-moment contribution to be zero at 0° angle of incidence and to be linear at angles of incidence up to at least -4°) increased from -0.015 at a Mach number of 0.80 to a maximum of -0.018 at a Mach number of 0.98 (fig. 6).

Comparison of Aerodynamic Characteristics of Reinforced-Plastic Wing and Steel Wing

The relative flexibility of the two wing configurations investigated was approximately $2\frac{1}{2}$ to 1 as noted previously. The wing-tip twist for the

reinforced-plastic wing was estimated to be -0.9° at a Mach number of 1.00 and an angle of attack of 20° based on measured load distribution from pressure data for the wing and its static deflection properties. The wing-tip twist of the steel wing was estimated to be -0.4° for the same conditions.

The measured aerodynamic characteristics of the two wing-body configurations showed no large differences, but did establish a few significant trends. Although the initial lift coefficients of the two wings were identical (fig. 4(a)) the steel wing in the wing-body configuration developed slightly higher lift at the higher angles of attack. The pitching-moment lift-coefficient curves (fig. 4(b)) indicate identical stability characteristics at the lower lift coefficients, with the steel wing in the wing-body configuration slightly more stable at the higher lift coefficients. The regions of unstable pitching moment at the highest lift coefficients are essentially duplicated.

CONCLUSIONS

An investigation of the static longitudinal stability characteristics of an all-steel wing and a plastic wing reinforced by a steel core was made in the Langley 16-foot transonic tunnel. The wings were geometrically identical with 30° sweepback of the quarter-chord line, a taper ratio of 0.2, and NACA 65A004 airfoil sections and were tested with and without a horizontal tail. The results indicate the following conclusions:

1. The wing-body configuration with horizontal tail was longitudinally stable throughout the Mach number and angle-of-attack ranges of these tests.

2. The wing-body configuration with and without the horizontal tail increased in stability with Mach number. For the tail-off configuration this increase was equivalent to a rearward movement of the aerodynamic center of about 13 percent of the mean aerodynamic chord between the Mach numbers of 0.80 and 1.03; a 10-percent shift occurred for the tail-on configuration.

3. No large differences were found in the aerodynamic characteristics of the all-steel and reinforced-plastic wings; therefore, the acceptability of the reinforced-plastic construction for wings of these general geometric characteristics is indicated.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 11, 1957.

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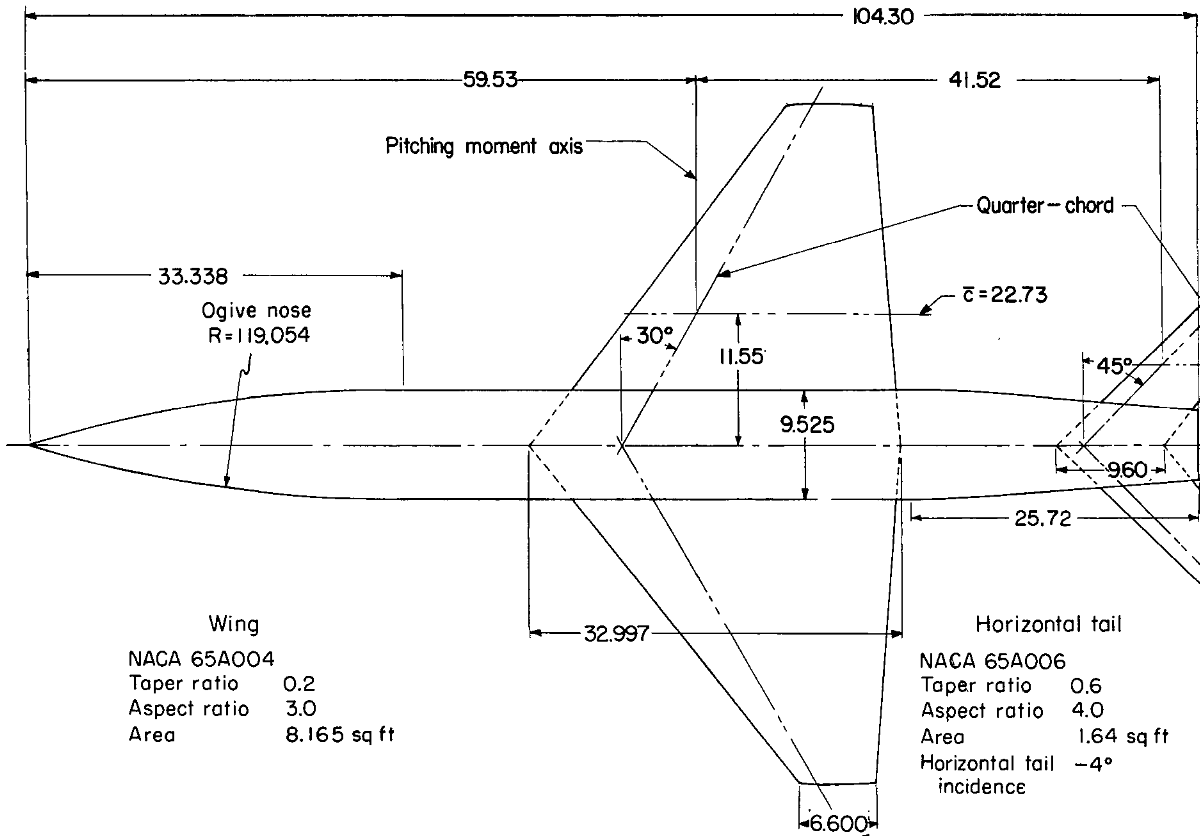


Figure 1.- Model details. (All linear dimensions in inches.)

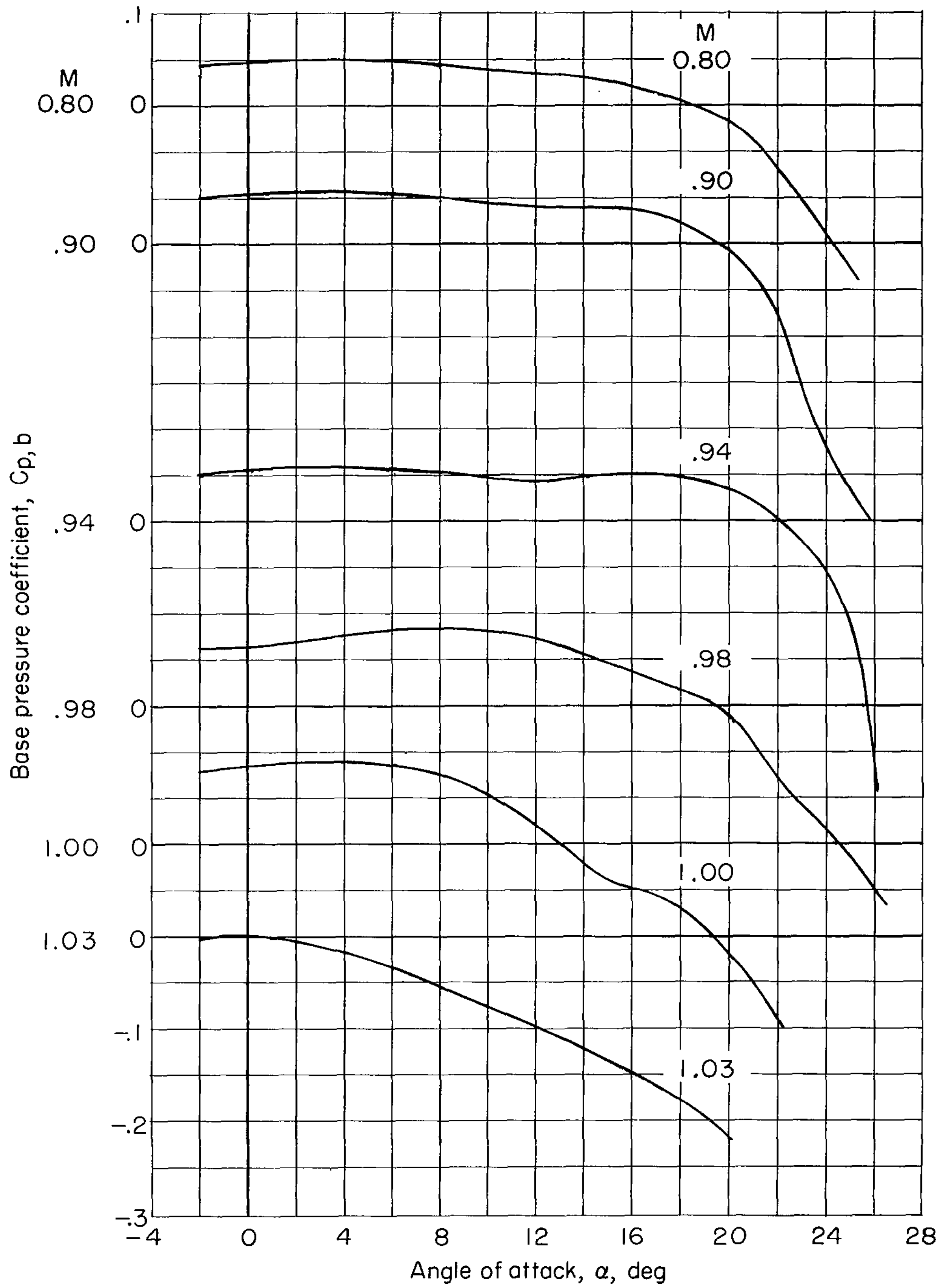
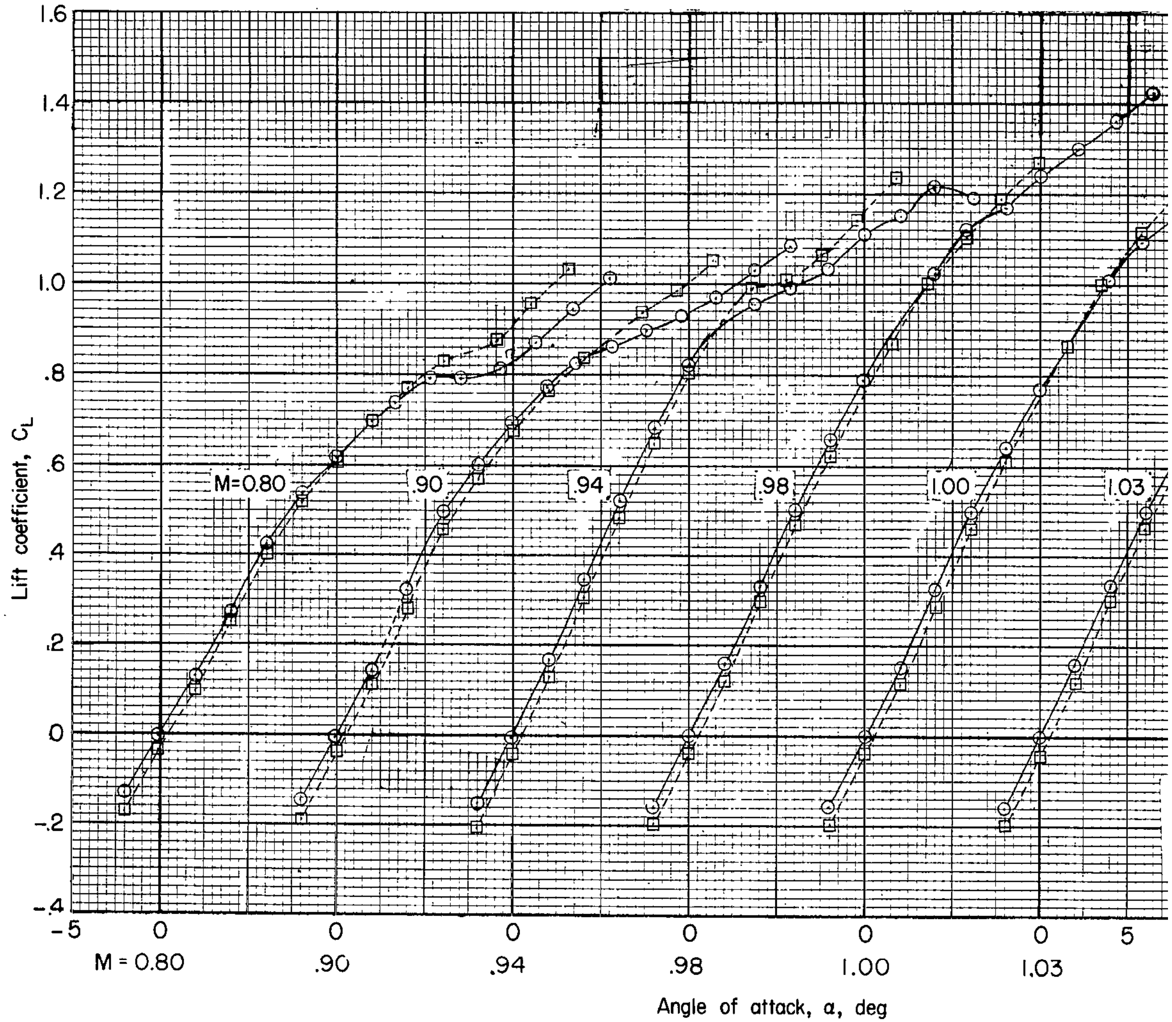
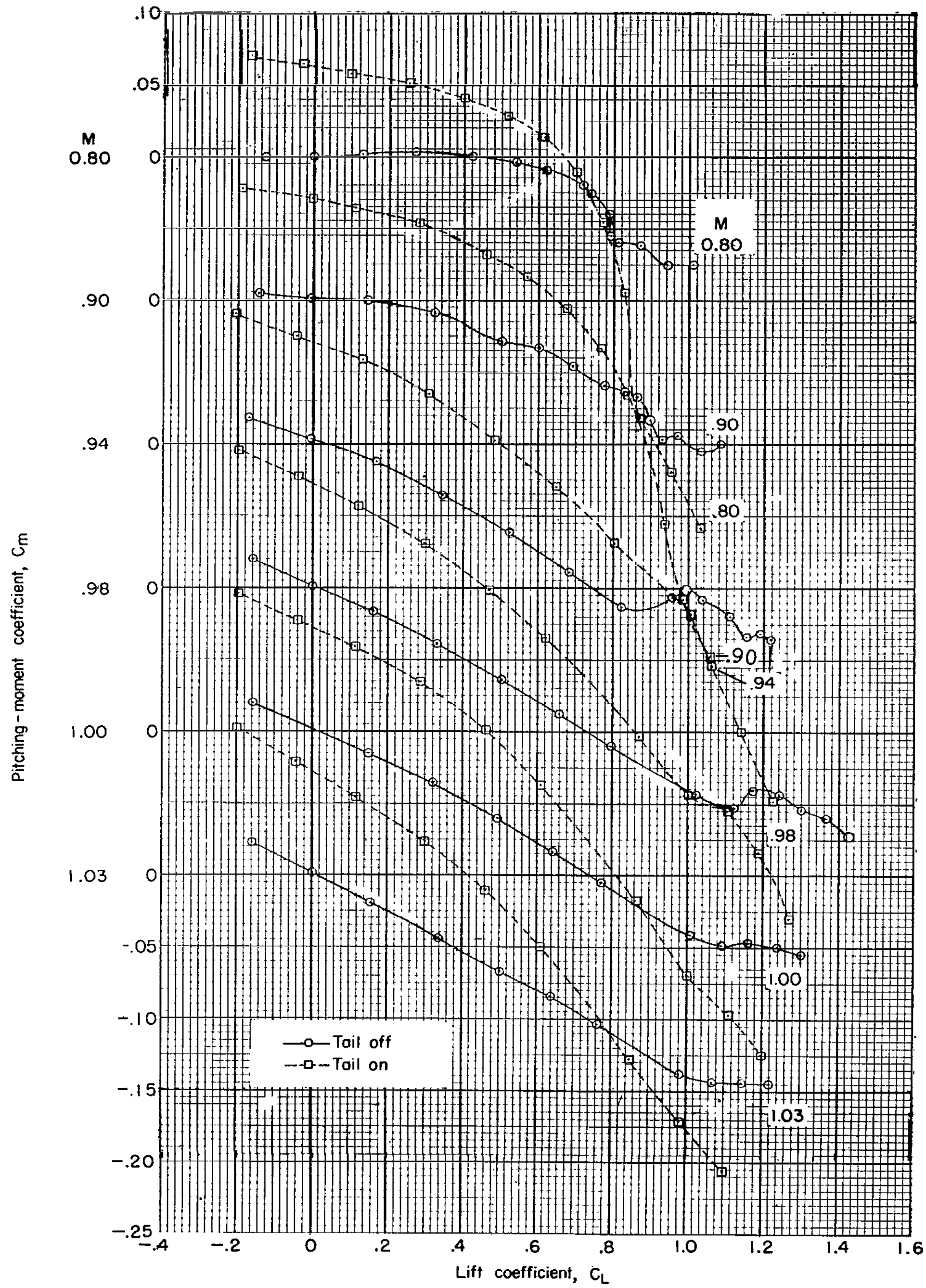


Figure 2.- Variation of base-pressure coefficient with angle of attack for all Mach numbers.



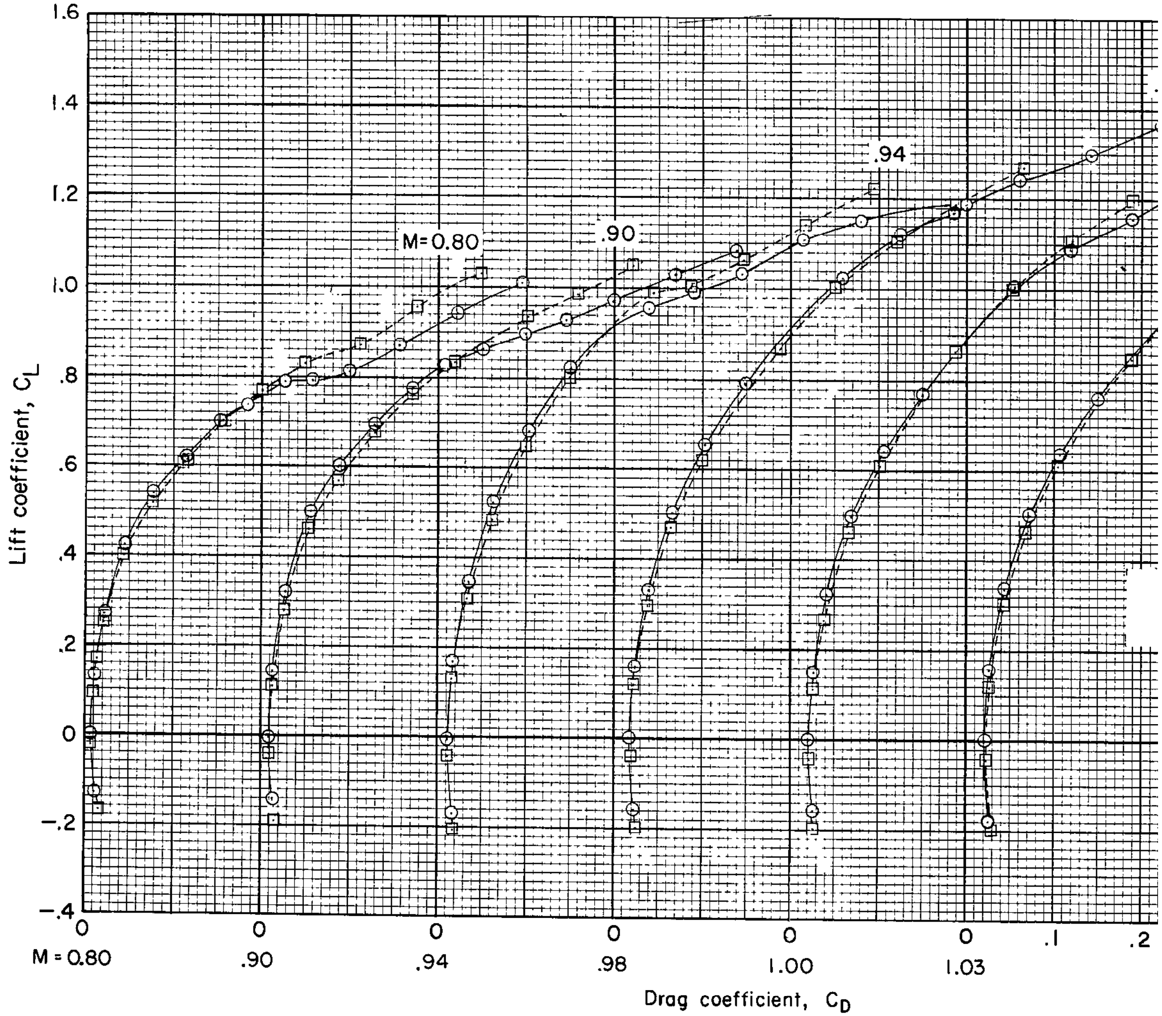
(a) Lift coefficient.

Figure 3.- Effect of horizontal tail on aerodynamic characteristics of reinfor
in a wing-body configuration. Horizontal tail mounted at -4° incid



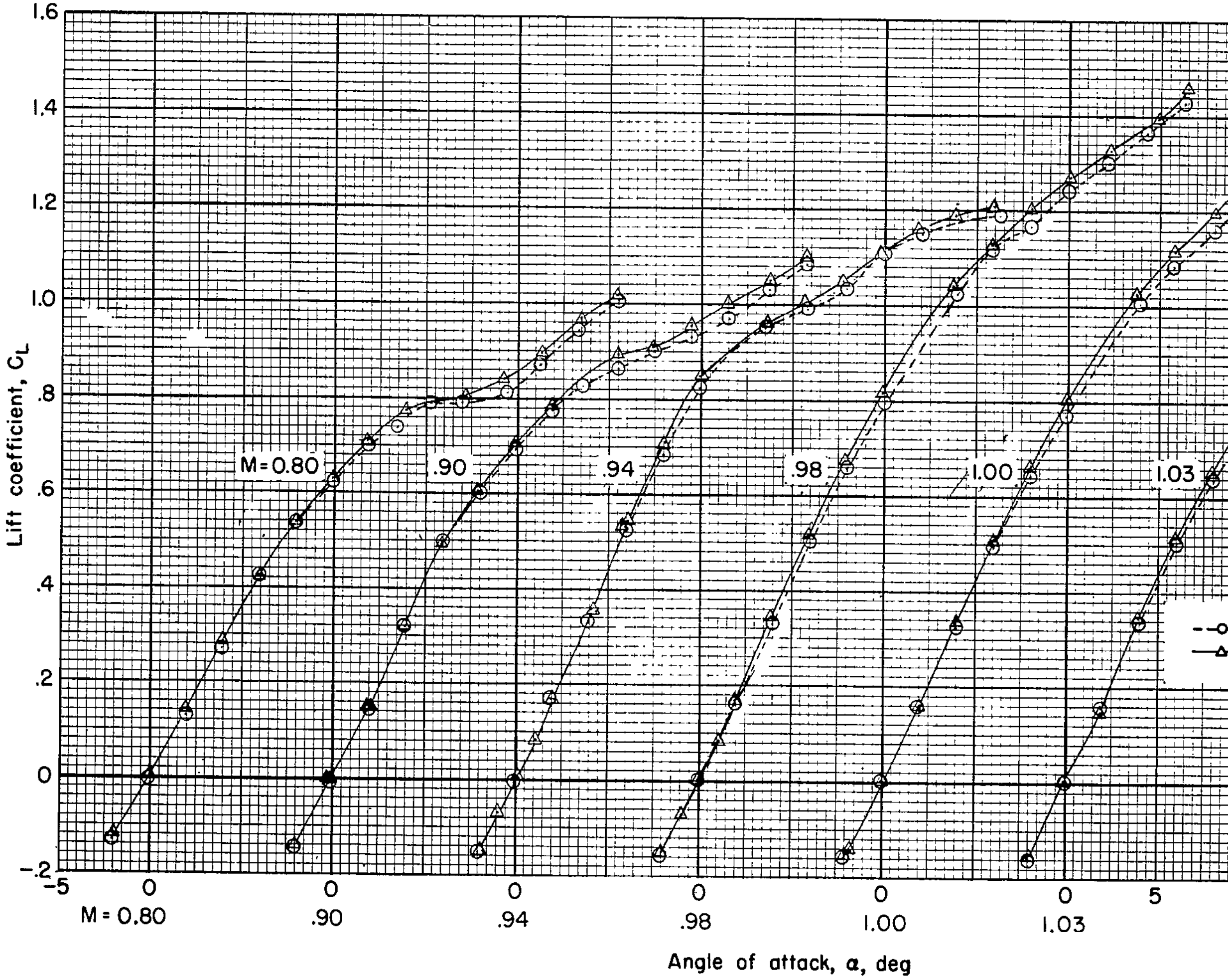
(b) Pitching-moment coefficient.

Figure 3.- Continued.



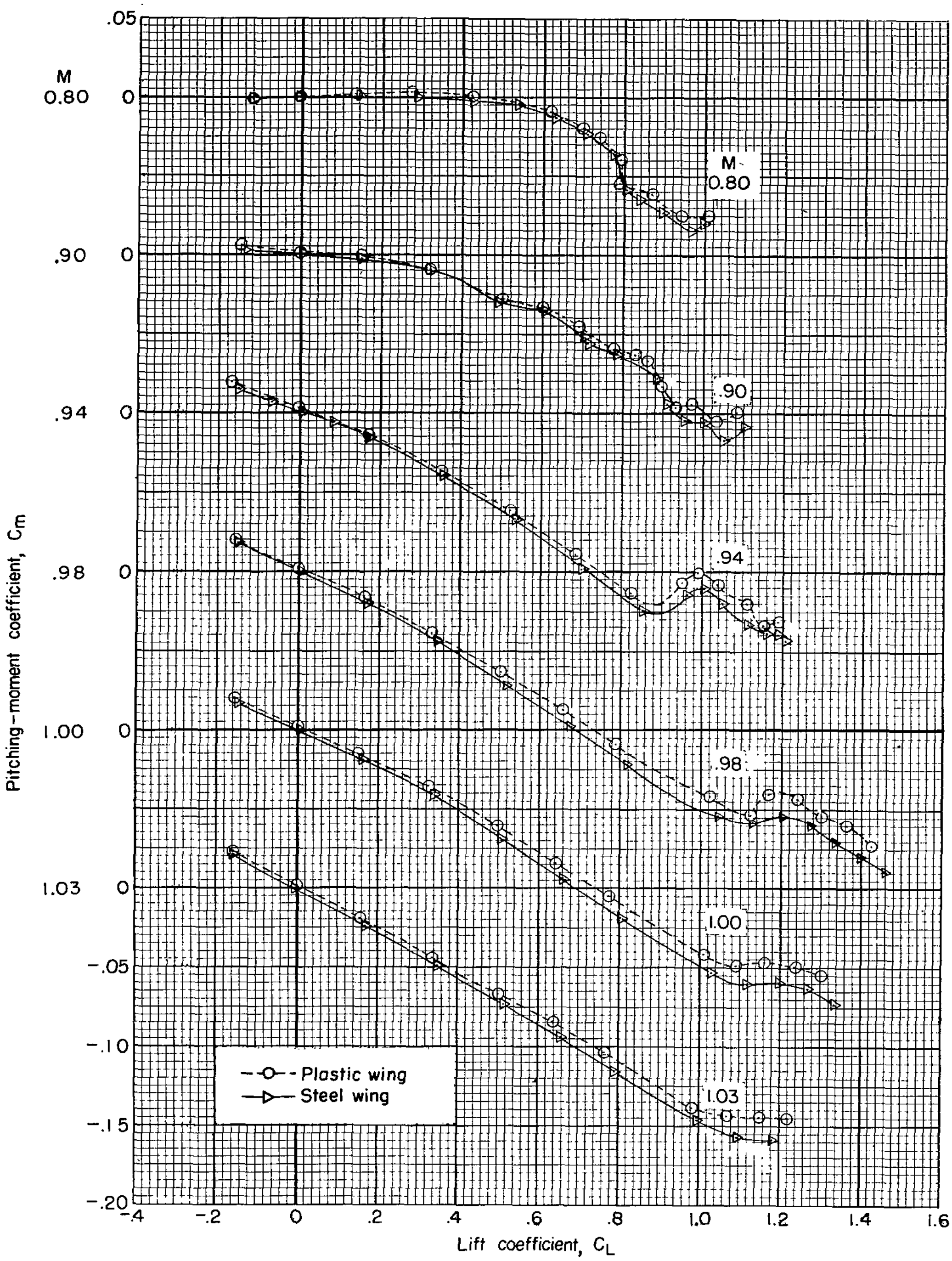
(c) Drag coefficient.

Figure 3.- Concluded.



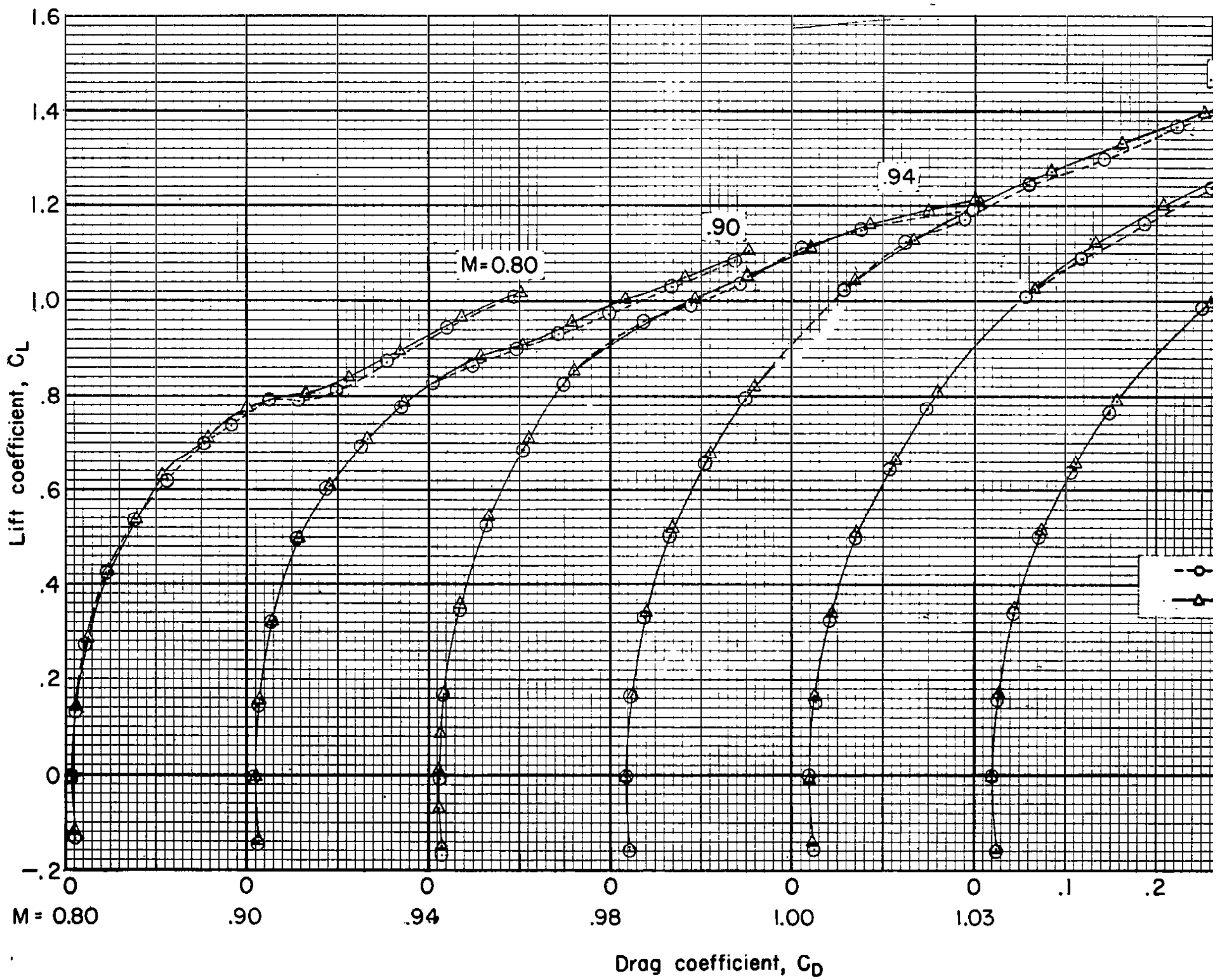
(a) Lift coefficient.

Figure 4.- Comparison of aerodynamic characteristics of steel and reinforced-pla
wing-body configuration.



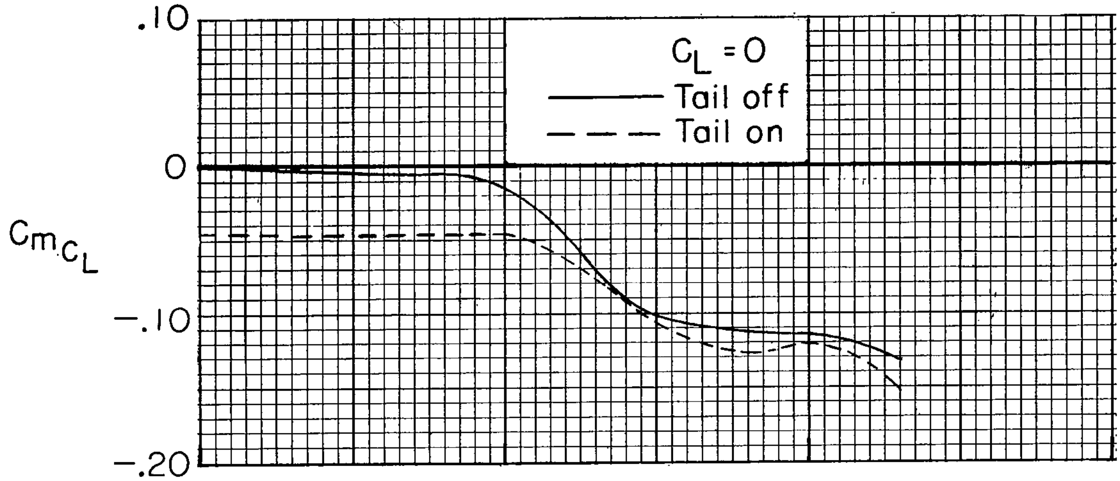
(b) Pitching-moment coefficient.

Figure 4.- Continued.

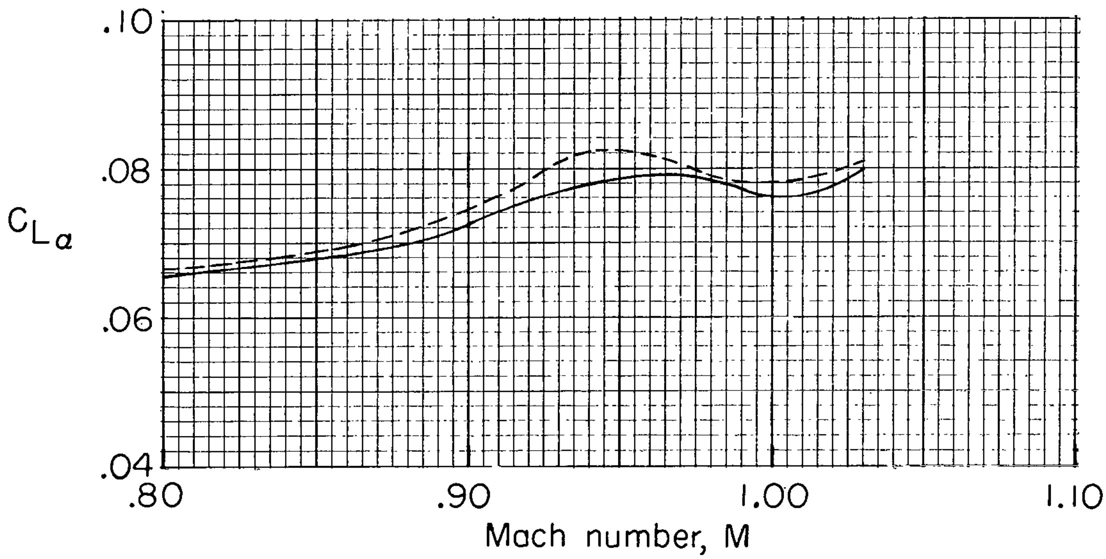


(c) Drag coefficient.

Figure 4.- Concluded.



(a) Longitudinal stability parameter.



(b) Lift-curve slope.

Figure 5.- Longitudinal stability parameters and lift-curve slopes as functions of Mach number for wing-body configuration of reinforced-plastic wing, with and without horizontal tail.

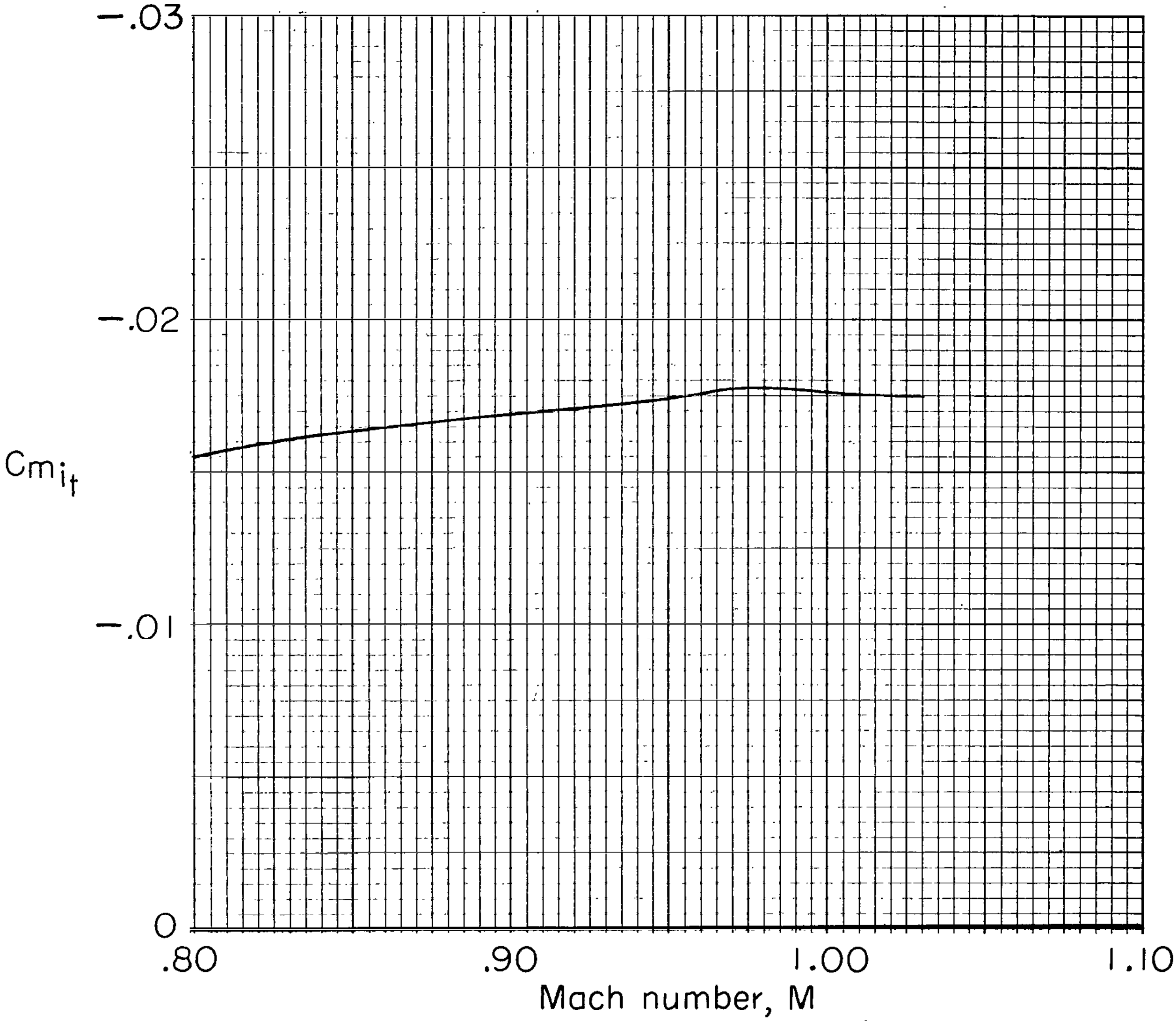


Figure 6.- Variation of horizontal-tail-effectiveness parameter with Mach number for wing-body configuration with reinforced-plastic wing.

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